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Fusion of Image Data for Human Understanding Using Array Architectures

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We have been pursuing the development of image and video fusion algorithms suitable for implementation on analog array hardwares, such as the CNN Universal Machine. We are attempting to develop source independent algorithms which produce a fused image which contains all the features from the source images which are relevant to a human observer.

Linear spatial filtering is the workhorse of complex image processing algorithms, and image fusion is no exception. Since we intend to use the CNN Universal Machine (CNN-UM) for image and video fusion, implementation of arbitrary linear filtering operations is a important capability.

It has long been understood that the B-template can be used for simple convolutions, but are limited to FIR filters of the same size as the template radius, typically of 3×3 support. By using the A-template, stable IIR filtering can be performed during a single CNN transient, but only a limited class of filters can be implemented, again imposed by the limited degrees of freedom of the CNN templates.

We have been investigating the use of multiple CNN filtering operations to implement a wider range of filters by means of a CNN Universal Machine algorithm. In general, each stage is a CNN transient using simple A- and B-templates. Former methods which cascade B-template operations only can be considered as a special case. Explicit transfer functions can be written in terms of A- and B-templates for each possible sequence of series and/or parallel combination. Certain restrictions must be placed on the template elements to guarantee stability or a desired stability margin.

When approaching the design problem from an optimization point of view, it is important to eliminate redundant degrees of freedom as well as assign parameters that can be fixed by external considerations. We have shown how arbitrary multiplicative constants can be removed even in the presence of constraints. Furthermore, a prototype filter design technique was used to account for pre-determined frequency-domain symmetry properties of the desired filter.

The basic design approach proposed is to consider a desired transfer function in the frequency domain. An optimization problem is then formulated depending on the number of desired stages and margin of stability (robustness). A nonlinear frequency-weighted least-squares optimization algorithm is utilized. The frequency-weighting scheme allows the

designer some control of the relative importance of the various regions of the transfer characteristic. Heuristics for choosing the initial parameter vector for the optimization routine have been derived.

Several example designs have been performed. One- two- and three-Stage CNN-UM algorithms were generated to approximate the ideal low-pass filter, human visual system model filter, and a Gabor-type (Gaussian band-pass) filter, all of which can be used in image fusion algorithms. The results show that by using only 3×3 templates and only a few CNN filtering stages, excellent approximations can be found which rival or exceed those previously reported with 5×5 templates.

Publications

- K. R. Crounse and L. O. Chua, "Determination of Edge Magnitude and Orientation Revisited – Practical Methods for the CNN Universal Machine," in *Proceedings 1999 Int'l Symposium on Nonlinear Theory and Its Applications*, vol. 1, pp. 427–430, Dec. 1999.

- K. R. Crounse, C. Wee, and L. O. Chua, "Linear Spatial Filter Design for Implementation on the CNN Universal Machine," in *Sixth IEEE International Workshop on Cellular Neural Networks and Their Applications, Proceedings*, to appear, May 2000.

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